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Detection of Deterioration or Infection of Homograft and Porcine Xenograft Bioprosthetic Valves in Mitral and Aortic Positions by Two-Dimensional Echocardiographic Examination

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Results of two-dimensional echocardiographic examinations were compared with angiographic, hemodynamic and surgical results in 44 patients with bioprosthetic valves in mitral and aortic positions who were undergoing elective or urgent reinvestigation 24 to 87 months (mean 34) after implantation. In these patients, there were 18 homograft aortic valves in the aortic position, 9 stent-mounted homograft aortic valves in the mitral position, 13 porcine xenograft valves in the mitral position and 12 in the aortic position.

Poor cusp support, gross fluttering and prolapse of cusps behind or below the anulus identified aortic insufficiency by two-dimensional echocardiography in six patients with an aortic homograft and four patients were identified with insufficiency of a stent-mounted aortic homograft in the mitral position. Two-dimensional echocardiographic examination revealed mitral stenosis in three patients with a porcine xenograft valve in the mitral position and suggested mitral insufficiency in two others. Bacterial endocarditis on homograft or porcine xenograft valves was associated with easily imaged vegetations by two-dimensional echocardiography in 10 patients.

Despite difficulties in imaging valve cusps, and the skill required to obtain good echocardiographic images of bioprosthetic valves, significant valve deterioration or infected prostheses were quite effectively imaged by two-dimensional echocardiography in this study.

Long-term follow-up results for valve replacement with bioprosthetic valves have suggested a significant incidence of valve degeneration, especially in younger patients (1–4). Two-dimensional echocardiography has made it possible to noninvasively obtain high quality images of bioprosthetic valves in postoperative patients that are much better than the images obtained of nonbiologic valves (5,6). The purpose of this study was to evaluate the utility of two-dimensional echocardiographic examination for identifying patients with deterioration or infection of two kinds of bioprosthetic valves.

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Methods

Study patients. All patients who had valve replacement with porcine aortic xenograft or human homograft aortic valves and who underwent cardiac catheterization (or operation for valve problems without prior catheterization) at Green Lane Hospital, Auckland, New Zealand or at the University of Arizona Health Sciences Center, Tucson, Arizona over a period of 24 months were included in this prospective study. Specifically, the study was designed to evaluate the utility of two-dimensional echocardiography for providing noninvasive diagnosis of valve dysfunction. There were 48 patients, of whom 22 were male and 26 were female; their ages ranged between 12 and 42 years (mean 31). The study group was unselected and contained a consecutive series of patients studied (electively or urgently) 24 to 87 months (mean 34) after valve replacement surgery. Twenty patients underwent follow-up catheterization studies 5 years after valve implantation and the others underwent more urgent evaluation for suspected valve infection or deterioration. The echocardiographic interpreters, however,

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Table 1. Degenerative Complications of Bioprosthetic Valves

Type of Valve	Position	Two-Dimensional Echocardiographic Observations	Angio/Cath/Surgical Observations	Comments
Free hand-mounted homograft	Aortic (n = 18)	6 gross flutter prolapse	10 aortic insuf (4 triv, 6 mod)	4 false neg for triv insuf
Stent-mounted homograft	Mitral (n = 9)	4 gross cusp prolapse + flutter	5 mitral insuf	1 false neg
Porcine xenograft	Aortic (n = 12)	None "abnormal"	1 mod aortic insuf + cusp tear	1 false neg
Porcine xenograft	Mitral (n = 13)	2 unsupported, 3 thickened, stenotic	2 mitral insuf, 4 mitral sten (>15 mm Hg gradient)	2 false neg for stenosis, 1 false pos for stenosis (see text)

Insuf = insufficiency; mod = moderate; Neg = negative; Pos = positive; sten = stenotic, triv = trivial.

were unaware of the clinical status of the patients when the studies were reviewed in a coded and blinded fashion.

Thirty of the 44 patients with successful imaging had a bioprosthetic valve in the aortic position (18 free hand-mounted aortic homografts, 12 porcine xenografts). Twenty-two patients had a bioprosthetic valve in the mitral position (9 stent-mounted aortic homografts, 13 porcine xenografts). Thus, the 44 patients who had successful imaging and are included in the Results section had a total of 52 bioprosthetic valves, 8 patients having 2 bioprosthetic valves. Thirty-two patients underwent hemodynamic investigation and 15 patients underwent surgery and, therefore, had surgical inspection of their valves for validation of the echocardiographic examination.

Echocardiographic studies. Two-dimensional echocardiographic studies were performed using a commercially available Toshiba SSH 10A, 2.4 MHz range focused, phased array sector scanner or an Electronics for Medicine/Honeywell, 3.5 MHz mechanical sector scanner with quantitative pulsed Doppler capabilities (six patients). Complete echocardiographic examinations in all standard views were obtained emphasizing the imaging of prosthetic valve cusps (7). The two-dimensional echocardiographic illustrations used in this paper were made from stop action, single frame video images with a Polaroid camera system.

Results

A technically adequate two-dimensional echocardiogram with images of the valve in question was obtained in 44 of the 48 patients. Adequate imaging consisted of visualization of the ring and the strut for stented valves and the valve cusps in systole and diastole for all valves.

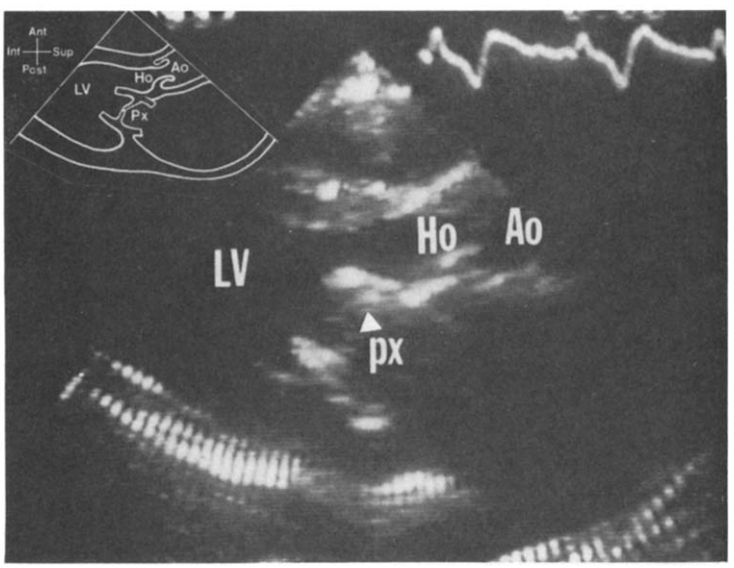


Figure 1. Echocardiogram in long-axis view in systole shows the thin cusps of free hand-mounted aortic homograft (HO) in the aortic (AO) position in a patient who also has a porcine xenograft (px) mitral valve prosthesis. There is a difference between the thickness of the cusps as imaged on the two types of valves. Note that the anterior leftward cusp of the porcine valve (**arrowhead**) is thicker than either of the cusps of the homograft valve. Ant = anterior; Inf = inferior; LV = left ventricle; Post = posterior; Sup = superior.

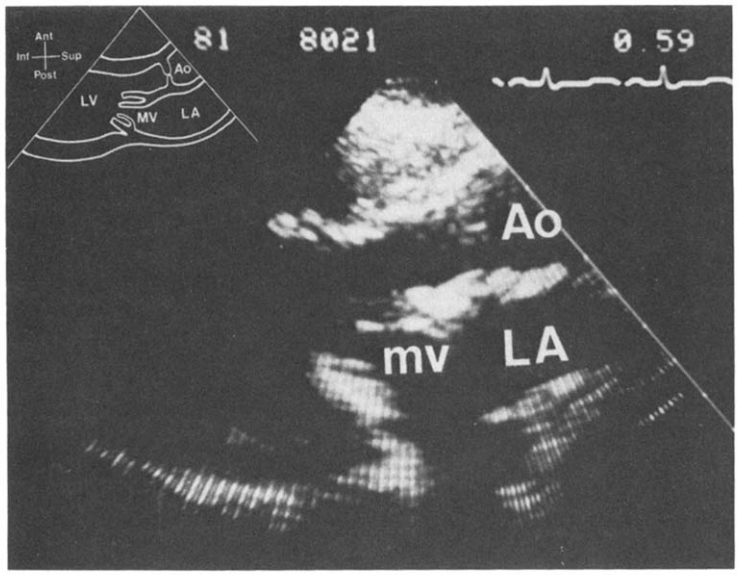
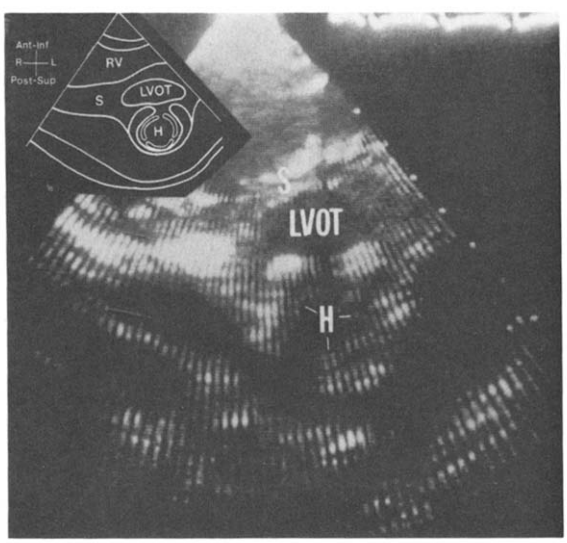


Figure 2. A long-axis image is shown of the thin symmetric cusps of a stent-mounted aortic homograft (mV) in the mitral position. LA = left atrium; other abbreviations as in Figure 1.

Findings in Normal Bioprosthetic Valves

Eighteen normal bioprosthetic valves were imaged in the 44 study patients (Table 1). The leaflets of the normal bioprostheses were imaged in mitral and aortic positions. The sewing ring and all three stents of the normal valves were visualized and had a smooth contour without extraneous adjacent echoes (Fig. 1 to 3). The valves were well anchored to the valve ring and moved symmetrically with it. Homograft valve cusps were thin and opened widely. In contrast, the anterior leftward cusps of the porcine heterografts often did not appear to have opened quite as widely as the other cusps in normal functioning valves. Thicker and slightly brighter echoes in the normal porcine heterograft were usually seen in oblique views of the left cusp and relate to the known asymmetry of the porcine aortic valve (Fig. 4) (4).

Figure 3. Short-axis view shows symmetric complete opening of a stent-mounted homograft valve (H) in the mitral position. L = left; LVOT = left ventricular outflow tract; R = right; RV = right ventricle; S = septum.



Abnormal Valves (Table 1)

Angiography or surgery showed that 22 implanted bioprosthetic valves were stenotic or had some degree of insufficiency.

Of the 18 aortic homograft valves in the aortic position, 6 showed gross fluttering and inferior prolapse on two-dimensional echocardiographic examination (Fig. 5). Ten of the 18 valves were regurgitant by angiography; in four patients, regurgitation was trivial. Of the nine stent-mounted aortic homografts in the mitral position, four showed gross cusp prolapse and fluttering (Fig. 6). Five of the nine were moderately regurgitant on angiography (one false negative finding by echocardiography occurred in a valve that was regurgitant by virtue of a perivalvular leak not associated with valve dehiscence).

Of the 12 porcine xenograft valves in the aortic position, none showed abnormal support on echocardiography but 1 showed moderate aortic regurgitation on angiography in association with a cusp tear not detected on the echocardiographic examination (Table 1).

Of the 13 porcine xenograft valves in the mitral position, 2 valves had unsupported prolapsing cusps and 3 appeared thickened and stenotic (Fig. 7) with poor cusp motion in excess of the minimal asymmetry and thickening in normal valves. Two of the 13 were regurgitant on angiography, and 4 of 15 patients with a porcine valve in the mitral position had a mean pressure gradient greater than 15 mm Hg at catheterization. Nonetheless, one valve considered to be

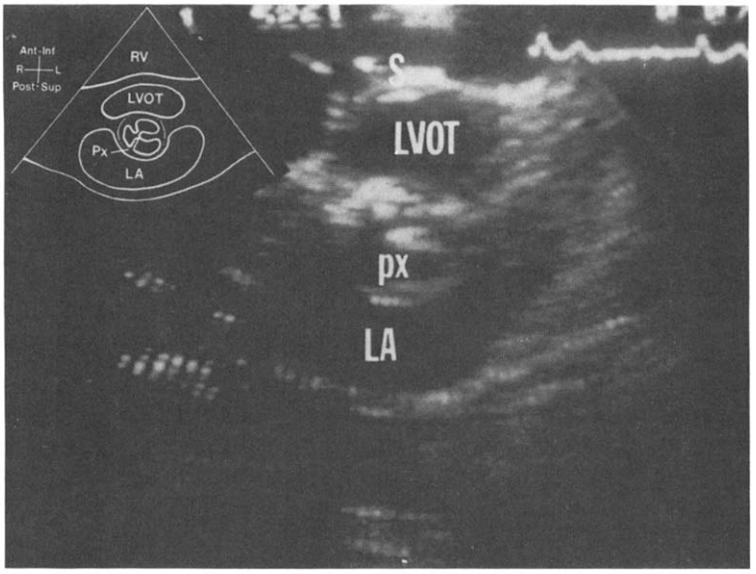


Figure 4. Short-axis view shows slightly more exaggerated asymmetry of a porcine valve (px) that had been in place only 6 months and was functioning normally. Again, the left commissure appears prominent and slightly thickened. The patient had been studied because of insufficiency of an aortic homograft in the aortic position. LVOT = subaortic left ventricular outflow tract; other abbreviations as before.

possibly stenotic on echocardiography had only a 5 mm Hg gradient at catheterization. Hemodynamically significant stenosis was not detected by echocardiography for two other valves (Table 1). Therefore, there were two false negative and one false positive diagnoses of mitral stenosis of a porcine xenograft in the mitral position.

Valve Infections

Twelve patients went to surgery with a diagnosis of bacterial endocarditis on a bioprosthetic valve. There were eight aortic valves (five porcine, three free hand-mounted homograft) and five mitral valves (two porcine and three homograft) implanted in these patients (Fig. 8 and 9). Prosthetic valve endocarditis was correctly diagnosed and vegetations were imaged by echocardiography in 10 of these 12 patients. There were two false negative interpretations for detection of infectious changes in this series. In the first case, a porcine mitral valve was infected in a patient who also had subacute bacterial endocarditis on a native aortic valve. The vegetations were imaged on the native aortic valve but were missed on the mitral valve prosthesis. In the second case, vegetations on a porcine xenograft valve in the aortic position were also missed on echocardiography, and the valve was seen at surgery to be infected with a small vegetation and a central perforation. The patient had been

Figure 5. Long-axis view shows inferior prolapsing of an aortic (Ao) homograft valve **(arrow)** associated with aortic insufficiency and cusp degeneration. Abbreviations as before.

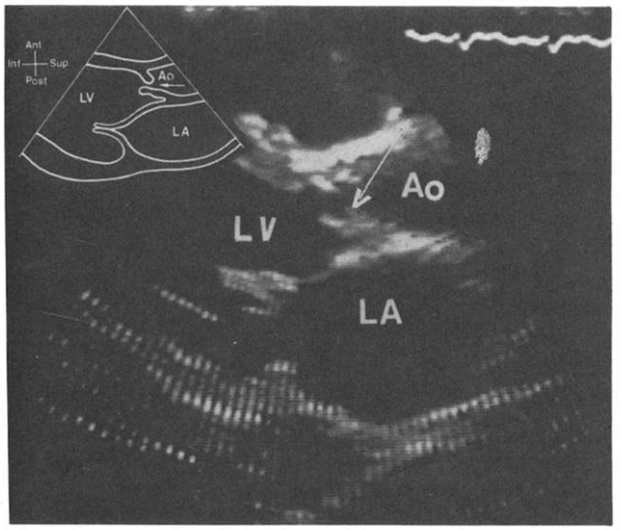
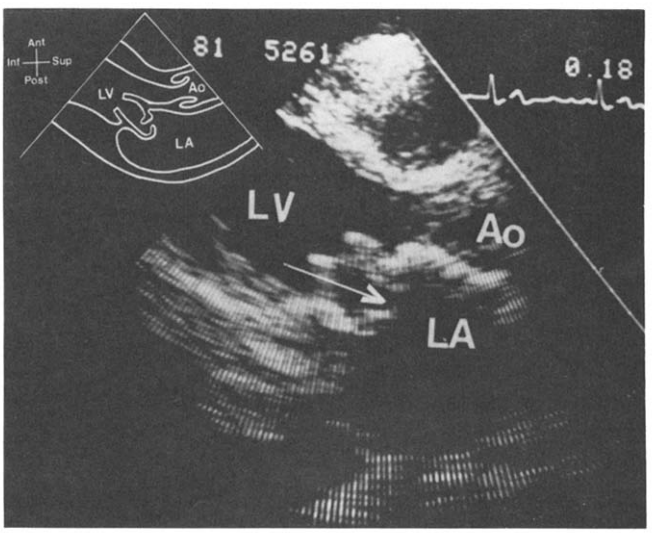


Figure 6. Long-axis view shows prolapse superiorly and posteriorly of one of the cusps of a stent-mounted aortic homograft in the mitral position **(arrow)** associated with mitral insufficiency. Abbreviations as before.



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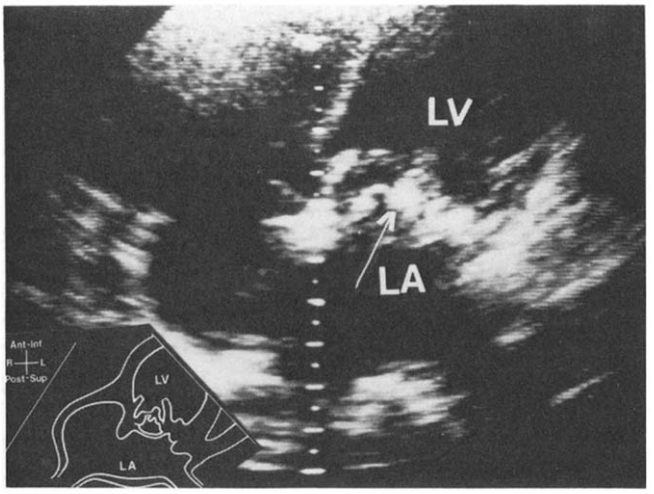


Figure 7. Oblique short-axis view shows two bulbous thickenings on the leaflets of a porcine heterograft in the mitral position **(arrow).** This valve was not only thickened but moved poorly and was stenotic at catheterization. Abbreviations as before.

referred for surgery because of persistently positive blood cultures and angiographic evidence of aortic regurgitation. One patient was correctly diagnosed by echocardiography as having two infected porcine valves (Fig. 9).

Perivalvular abscess and aneurysm. Two-dimensional echocardiographic examination was also capable of diagnosing perivalvular abscesses and aneurysms. In this series, we observed one aortic homograft that had a perivalvular aneurysm (Fig. 8), and two dehisced valves that had an abnormal rocking motion and were also infected. One valve was a porcine xenograft in the aortic position; the other valve was a dehiscent porcine xenograft in the mitral position. One diagnosis of an abscess around a porcine xenograft valve in the aortic position was missed in a patient who had an echocardiographically correct diagnosis of bacterial endocarditis. This valve appeared well anchored at surgery.

Discussion

Bioprosthetic valves have a significant advantage over mechanical valves. There is decreased risk of thromboembolism without the use of anticoagulant therapy and, therefore, decreased risk of anticoagulant-related complications (8,9). The central flow orifice in bioprosthetic valves is more physiologic (8), and valve failure, when it occurs, is usually slowly progressive rather than sudden and potentially fatal (8).

Incidence of bioprosthetic valve failure. The long-term course of patients with bioprosthetic valves is, however, not free of complications, most commonly, infection (1,2,8,10) or spontaneous sterile valve degeneration (1,3,4,8,10), or both, causing restenosis or cusp degeneration and valve incompetence. This study did not examine the risk of any specific patient for valve failure. Patients admitted to the study prospectively were being reevaluated for a suspicion that they were not doing well or were at

Figure 8. Short-axis view of the supravalvular aorta shows two pockets of a perivalvular abscess (Absc) around an aortic homograft. The thin aortic homograft cusps are seen in the circle medial to the two pockets of the abscess. RA = right atrium; RVOT = right ventricular outflow tract; other abbreviations as before.

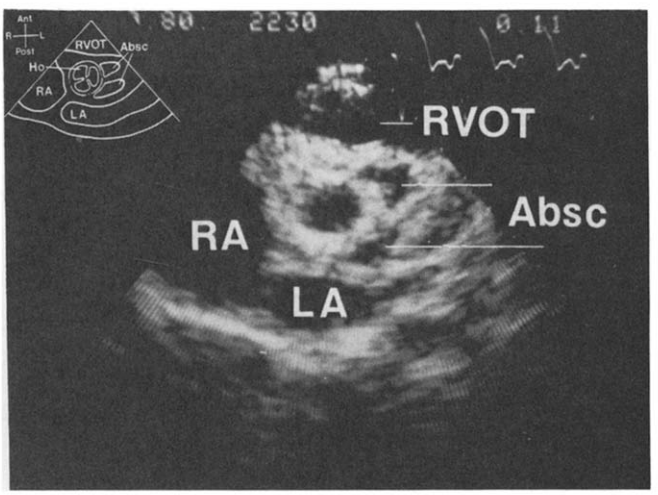
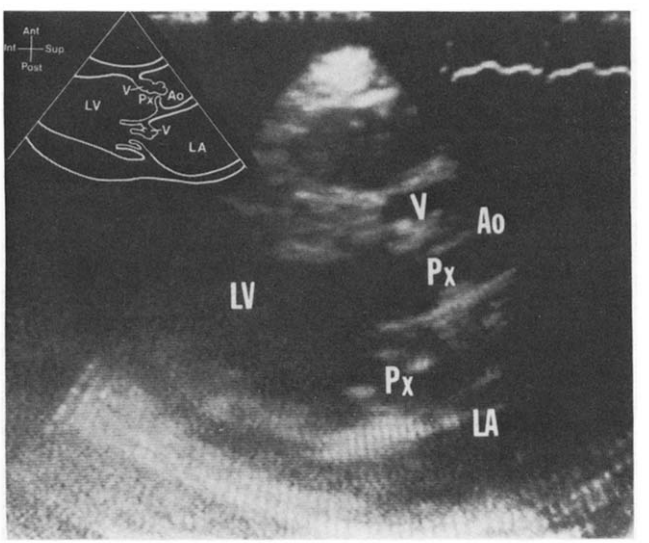


Figure 9. Vegetations (V) are shown on an infected porcine xenograft (upper Px) in the aortic (Ao) position. A small vegetation was also present on the porcine xenograft in the mitral position (lower Px) in this patient. Other abbreviations as before.



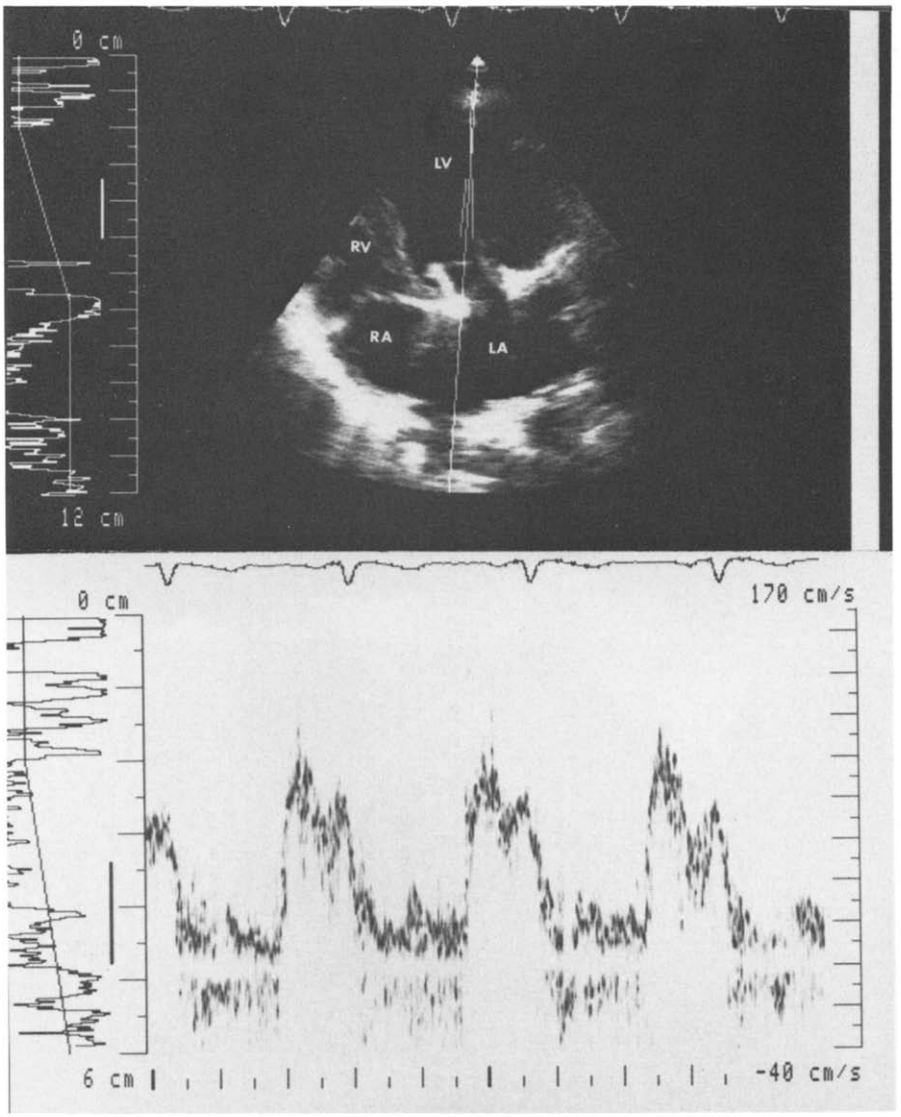


Figure 10. Interrogation of a normal porcine valve in the mitral position with a quantitative range gated pulsed Doppler two-dimensional echographic scanner from an apical four chamber view shows narrow spectral width and mitral valve peak velocities approximately 120 cm/s with a normal "m-like" waveform **(lower panel)**. The **solid line (upper panel)** is the direction of Doppler sampling and the **double line** along it shows the position of the Doppler sample volume within which the velocities were determined.

some risk for valve dysfunction. During the period over which these investigations were carried out, more than 600 patients with bioprosthetic valves were being followed up clinically in Auckland, New Zealand; in Tucson, 100 patients were being actively followed up more than 6 months postoperatively. The risks of valve degeneration for the types of prostheses studied have varied with methods of preservation and with the year of implantation. Deloche et al. (11), reporting on porcine valves, suggested that in their follow-up group there was an 8% incidence rate of valve failure over 6 years for commercially available porcine heterografts in the aortic position. Of the porcine aortic valves that failed in the aortic position in their study, 37% were removed because of infection, and the rest were removed because of some type of sterile valve deterioration. In the mitral position the total failure rate appeared to be slightly above 20%, with the vast majority of valves failing because of degeneration, and only 13% failing because of infectious endocarditis. This probably relates to the high incidence of valve degeneration in young rheumatic patients who received porcine valves in the mitral position (3). Moore et al. (12) analyzed a long-term experience with aortic valve homografts in patients followed up for as long as 10 years, and reported a 5% failure rate for noninfectious complications. Very mild aortic incompetence that is of no clinical significance and does not require reoperation has been more common in the New Zealand experience for free hand-mounted aortic homografts in the aortic position, occurring in approximately 12% of patients followed up from 4 to 6 years (13).

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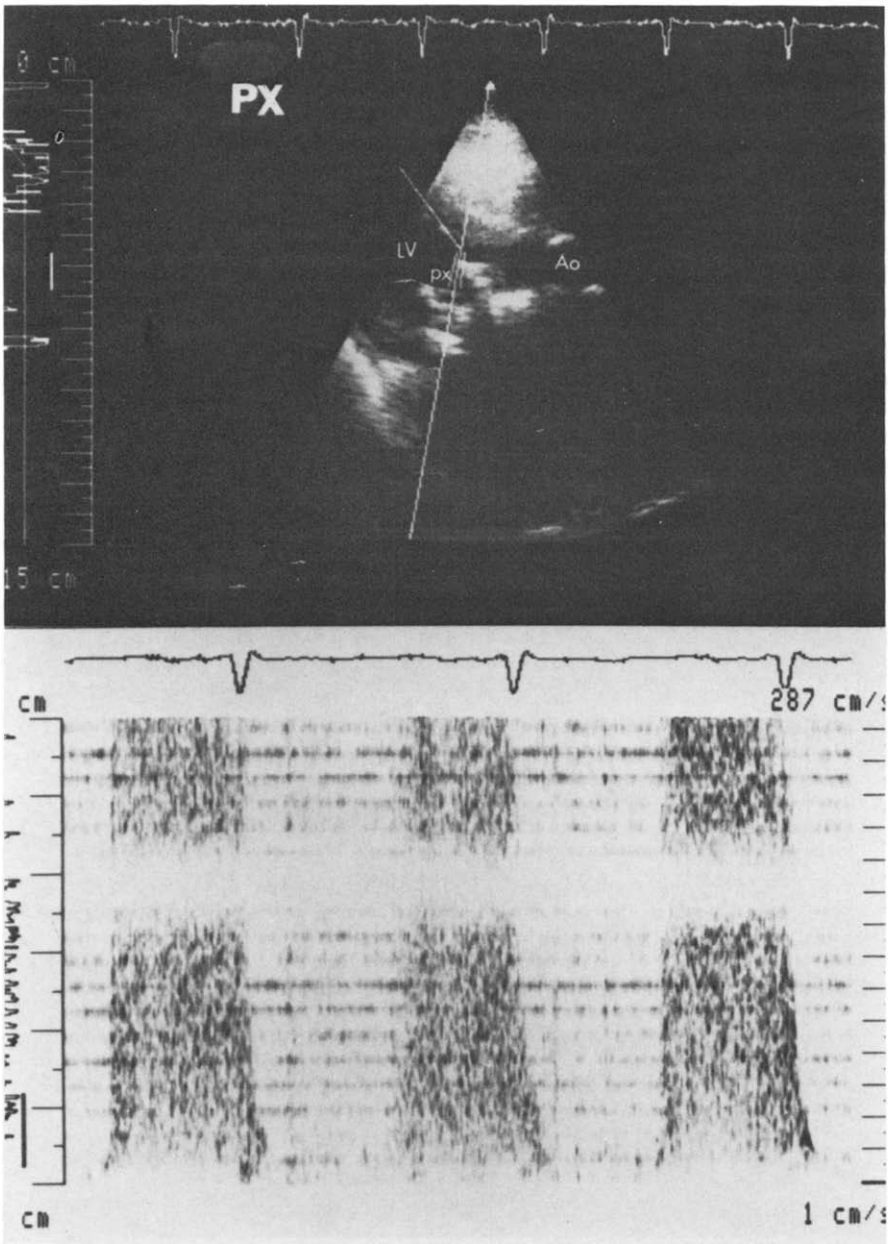

Figure 11. Long-axis view shows Doppler interrogation of a thickened porcine xenograft (Px) in the mitral position. The Doppler trace **(lower panel)** shows a broadened spectrum and very high velocities (above the high velocity detection limit for the scanner) associated with severe stenosis of this xenograft valve. Abbreviations as before.

Diagnostic accuracy of echocardiography. Two-dimensional echocardiography has proven itself previously in a small series of patients as an accurate noninvasive technique for the diagnosis of porcine prosthetic valve malfunction (5,6). The present study reports greater accuracy for achieving prospective diagnosis by two-dimensional echocardiography, particularly in comparison with studies reporting its use for evaluation of nonbiologic valves, but also in comparison with reported results for biologic valves in the United States (5) where homografts are rarely used. In our experience, it was much easier to image and distinguish abnormally thickened aortic homografts than it was to evaluate the normally asymmetric porcine xenograft bioprostheses.

One method we utilized recently to assist in studying the patient with a porcine xenograft is Doppler flow interrogation. Our experience has been that serial studies tracking transvalvular flow velocity across prosthetic mitral valves, when obtained with a quantitative two-dimensional echocardiographic Doppler flowmeter, have aided significantly in the early diagnosis of porcine xenograft malfunction, especially stenosis (Fig. 10 and 11). Transvalvular flow velocities increase dramatically across deteriorating valves as they become stenotic.

Our study emphasizes the observation that motion of the cusps of the normal porcine xenograft is not symmetric. This was recently demonstrated by Temkin et al. (14), who showed that in video images of xenograft valve motion during pulsatile flow in a flow model at low volume flows near 2 liters/min, the thicker cusp on the left side was only partially opened. Such partial opening of the porcine xenograft valve especially in the mitral position detected by the two-dimensional examination makes cusp motion alone quite unreliable as an indicator of valve function. Our early experience with Shiley-Ionescu valves is that they appear thicker on echocardiography than to homografts but behave symmetrically.

Clinical implications. Two-dimensional echocardiography can detect thickened, degenerated, prolapsing or poorly supported cusps of bioprosthetic valves in the aortic or mitral position. Homograft valves are thinner and easier to image and follow-up serially postoperatively than are porcine xenografts. Two-dimensional echocardiography can sometimes miss significant porcine xenograft mitral stenosis because the valve is often asymmetric in appearance and in motion, even when functioning normally. Echocardiography is, however, fairly sensitive for the diagnosis of bacterial endocarditis and perivalvular abscesses, especially in those cases associated with valve dehiscence. Finally, we believe serial quantitative two-dimensional echocardiographic Doppler studies, especially when compared with an initial flow analysis in the early postoperative period, may prove to be an important method for evaluating prosthetic valve function.

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